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NEW EQUIPMENT FOR OBTAINING HOST MATERIAL FOR THE MASS PRODUCTION OF TRICHOGRAMMA MINUTUM, AN EGG PARASITE OF VARIOUS INSECT PESTS

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INTRODUCTION

During the 4 years in which the Albany, Ga., parasite laboratory of the Bureau of Entomology and Plant Quarantine has been engaged in mass production of *Trichogramma minutum* Riley for experimental use, numerous changes in technic and apparatus have been made with the idea of increasing the output of beneficial insects and of reducing the cost of production. As soon as any modifications proved their value they were adopted, and the older equipment and methods were discarded. So many changes have been made during the 4 years that the present equipment and technic have little resemblance to those used at the beginning. It is deemed advisable, therefore, to describe at this time the improvements in the apparatus and methods.

ORIGINAL EQUIPMENT AND TECHNIC

Mass rearing of *Trichogramma minutum* involves not only propagation of the parasites themselves but also the simultaneous production of vast numbers of host insects, in the eggs of which the parasites develop. The Angoumois grain moth (*Sitotroga cerealella* Oliv.) is the host used for this purpose in most of the production laboratories.

TRAYS FOR REARING SITOTROGA MOTHS

The original equipment for multiplication of *Sitotroga* in the Albany laboratory consisted of four incubator rooms, 12 by 16 feet

with 7-foot ceilings, provided with racks holding double tiers of trays or "drawers" of corn, the trays being 36 inches wide, 24 inches from front to back, and nearly 4 inches deep, with bottom of 1/6-inch galvanized hardware cloth (fig. 1). Each tray was loaded with a bushel of Yellow Dent corn, making a layer 3 inches deep. Infesta-

FIGURE 1.—Collecting moths of *Sitotroga cerealella* in an incubator room from trays of infested corn.

tion was started in this corn by the addition of eggs of *S. cerealella*, and development was accelerated by keeping the incubator rooms at 80° F. night and day and by spraying the rooms and infested corn twice weekly with water.

Adult moths were collected from these rooms after three developmental cycles of the host had been completed, or about 90 days after

the eggs were introduced. The moths were gathered daily with the aid of a vacuum sweeper into a battery jar equipped with a separating cover which prevented the moths from being drawn on into the machine (fig. 1). The battery jars containing the collected moths were fitted with 20-mesh brass screen-wire covers, held on with large rubber bands cut from inner tubes of automobile tires, and were kept in the oviposition racks for 3 days, the loose eggs being shaken through the screen-wire tops each morning (fig. 2). After cleaning

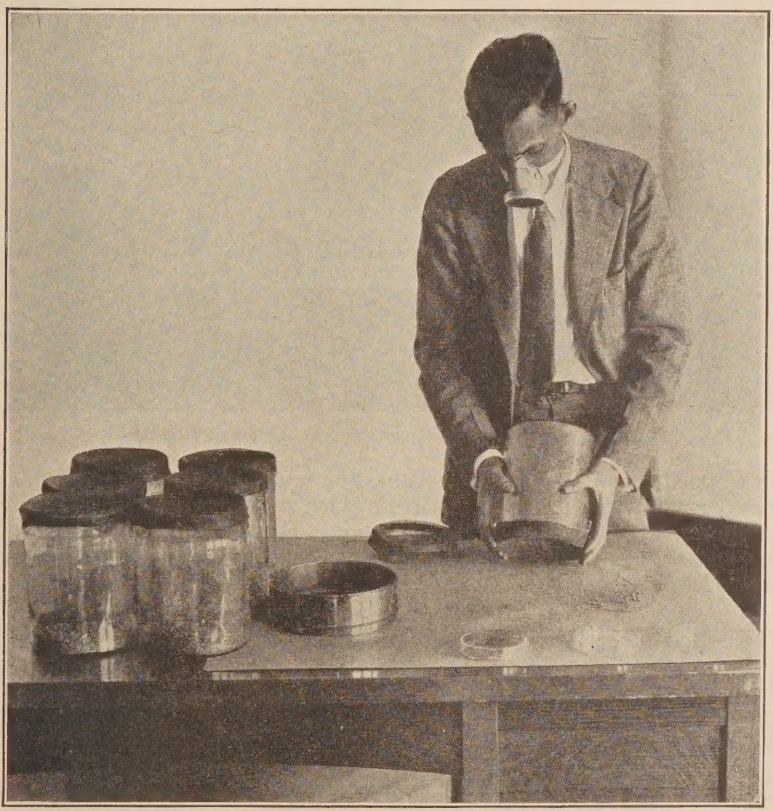

FIGURE 2.—Removing eggs of *Sitotroga* moths from egg-deposition jars by shaking them through screen-wire tops.

by fanning, the eggs were affixed with photograph paste (fig. 3) to circles of white cardboard. Each card was 3¼ inches in diameter and held approximately 50,000 eggs.

METHOD OF PROCURING PARASITIZATION

The parasite *Trichogramma minutum* was propagated in Petri dishes on a rack in an adjacent laboratory room (fig. 4). Ordinarily, one-fourth to one-half of a previously parasitized card of *Sitotroga* eggs was used as a "starter", and when the adult parasites had emerged a card of fresh eggs was inserted, and this was replaced on

the second day by another card. Four days after exposure to the parasites, the *Sitotroga* eggs in which *Trichogramma* was developing turned black, and 3 or 4 days later, at the 80° F. temperature, emergence of adults took place. In most of the field experiments, emerged adults of *Trichogramma* were liberated in orchards or fields from

FIGURE 3.—Pasting *Sitotroga* eggs to cardboard circles.

the Petri dishes used in production, but sometimes portions of parasitized cards were hung in the trees with fine magnet wire to allow emergence to take place in the open air. It was always necessary to keep one-eighth to one-fourth of all the parasites for use as starters in the laboratory.

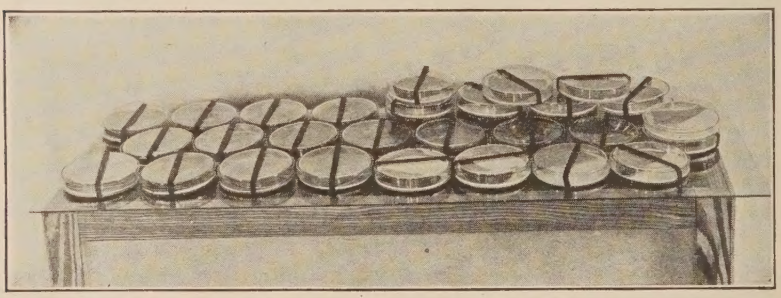

FIGURE 4.—Propagation of *Trichogramma minutum* in Petri dishes by the use of cards of *Sitotroga* eggs.

RESULTS OBTAINED IN 1931 AND 1932

In 1931 only two incubator rooms were in operation, but these produced a total of 25,444,000 *Sitotroga* eggs with this equipment and technic. The 1932 production was nearly 31,000,000. At the end of each rearing season a careful estimate was made of actual costs, including supplies, labor, heating, and depreciation on equipment, the last item being charged each year at one-tenth of the original cost.

None of the expenses connected with other experiments, in the field or laboratory, was included in these estimates, nor were the items of rent or cost of supervision.

The following tabulation shows in detail the expenses incident to the production of host eggs and the further handling of these in obtaining the desired parasites for the season of 1931:

Permanent equipment:		
Racks, incubator rooms	$81.00	
Trays, incubator rooms	345.00	
Refrigerator, electric	159.39	
Furniture	9.45	
Fans, incubator rooms	16.00	
Cans, fumigating	20.00	
Vacuum sweeper	32.00	
Thermometers	29.00	
Tops for jars	19.00	
Miscellaneous	8.65	
Total		$719.49
10 percent depreciation for year		71.95
Fuel (fuel oil)		63.75
Electricity, gas, water [1]		80.00
Glassware and miscellaneous supplies:		
Battery jars	20.52	
Petri dishes	13.00	
Graduated cylinders	2.52	
Paste	3.50	
Cardboard	.90	
Small items	8.63	
Total		49.07
Corn for rearing host insects, 200 bushels at $1.18 each		236.00
Labor:		
Moth collecting, 240 days, 4 hours each, at $0.15 per hour	144.00	
Cleaning eggs, 240 days, 1 hour each, at $0.40 per hour	96.00	
Pasting eggs, 25.5 hours at $0.40 per hour	10.20	
Parasite propagation, 240 days, one-half hour each, at $1 per hour [2]	120.00	
Cleaning glassware, 240 days, 1 hour each, at $0.15 per hour [2]	36.00	
Screening dirty corn	10.00	
Total		416.20
Total costs (1931) [3]		916.97
Cost per million *Sitotroga* eggs (25,444,000 produced)		36.04

There were but minor variations in some of the items in the work in 1932, but the cost per million of *Sitotroga* eggs was a little lower, as about a fourth more eggs were produced with only a slightly higher total cost. In 1931, 25,444,000 *Sitotroga* eggs were obtained at a cost of $916.97, or $36.04 per million. In 1932, 30,801,000 *Sitotroga* eggs were obtained at a cost of $1,043.35, or $33.87 per million.

LIMITING FACTORS AND DIFFICULTIES

While these production figures compared quite favorably with those of other laboratories where mass rearing was being carried on, and with current commercial prices for the parasites, still larger yields and lower unit costs were desired. The limiting factor in the

[1] Estimated. [2] Average. [3] Rental and cost of supervision not included.

laboratory mass production of *Trichogramma* was the number of host eggs that could be produced with the equipment described. If there had been available several times the number of host eggs actually produced, all could have been used for breeding parasites with only a small additional outlay for apparatus and labor. This desired increase in production of host material could have been obtained by utilization of more grain, in additional incubator rooms, fitted out with equipment of the same kind.

However, in the course of the production in 1931 and 1932, several rather serious defects appeared that led to a search for better host-rearing apparatus. In the first place the 3-inch layers of corn were wasteful, as the *Sitotroga* moths bred only in the kernels near the upper and lower surfaces. Shallower trays with only 1½ or 2 inches of corn would have produced as many moths as did the deeper trays, and in the same space there could have been a much larger number of them. When infestation became heavy in the incubator rooms, heating of the deep layers of corn occurred, and in hot weather this heat actually killed the *Sitotroga* stages and abruptly terminated production. Then, too, incubator rooms quickly became infested with such pests as gamasid mites, coleopterous weevils of several varieties, and a hymenopterous parasite (*Dibrachys boucheanus* Ratz.). While the mites and weevils could be kept under control without difficulty, the parasite *D. boucheanus* proved to be a serious menace to mass production of *Sitotroga*, as it could not be kept out of the incubator rooms even by the most careful screening with 60-mesh screen wire, and very soon after gaining entrance to the rooms it reduced the hosts almost to extinction.

IMPROVED EQUIPMENT AND TECHNIC

DESCRIPTION OF THE CABINETS

Upon the suggestion of S. A. Rohwer and C. P. Clausen, of the Bureau of Entomology and Plant Quarantine, mass rearing of *Sitotroga* in wheat was tried in small cabinets of several designs.[4] In these preliminary tests it was clearly demonstrated that wheat was superior to corn for mass rearing of *Sitotroga*, but the shallow horizontal trays used in all the cabinets for holding the wheat were unsuited to the climate of southern Georgia, as excessive heating of the infested grain occurred in hot weather. A cabinet of original design (fig. 5) remedying this and other unsuitable features was finally constructed in the laboratory. Essentially it consisted of a boxlike chamber, 29½ inches wide, 28 inches from front to back, and 24 inches high, supported on four legs 12 inches long. The framework was wood; the bottom, back, and top were of galvanized sheet iron; and the full-length door in front was of the same material. The sides were 60-mesh copper screen wire. The sheet metal and screening were tacked on the inside of the framework, so that the inside of the cabinet would have a minimum of angles in which the adult moths might lodge. Large tinned-metal funnels were soldered in inverted position over four 6½-inch holes in the metal top. Automatic collect-

[4] Stanley E. Flanders, of Riverside, Calif., Philip Garman, of New Haven, Conn., H. W. Allen, of Moorestown, N. J., and A. B. Baird, of Belleville, Ontario, kindly furnished unpublished details and photographs of their rearing cabinets.

ing cans of cylindrical shape (fig. 6), with 60-mesh screen tops and screw-on bottoms with inverted funnels attached, fitted closely over the funnels on the cabinet top.

Inside the cabinet narrow trays for the wheat (fig. 5) were hung vertically from a strip of wood on each side. Each tray was framed of one-half- by three-quarter-inch wood, and was 26 inches long, one-half inch thick, and 13½ inches deep. One side of each frame

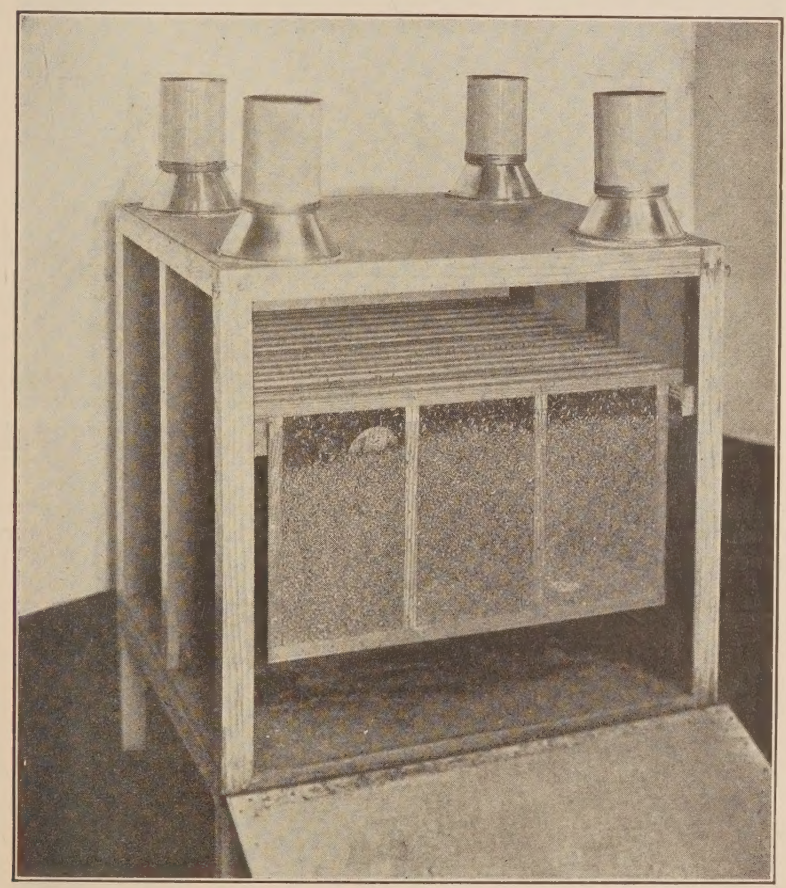

FIGURE 5.—The 1933 cabinet (Public Service Patent 1,974,549) with door open to show vertically hanging trays of infested wheat.

was completely covered with 12-mesh enameled screen wire, and the other was covered similarly, except that a narrow slot was left open at the top, so that the grain might be added to the tray easily, and might be removed when no longer suitable for rearing the moths (fig. 7).

OPERATION OF THE CABINETS

In the fall and winter of 1932–33 and the following spring, 16 of these cabinets were made and put into operation, and after several

experiments a routine procedure for starting infestation in these units was adopted. Seed wheat was fumigated in tight insecticide cans with carbon disulphide, and was stored in these containers until needed. For each cabinet, about 1½ bushels of this grain was soaked

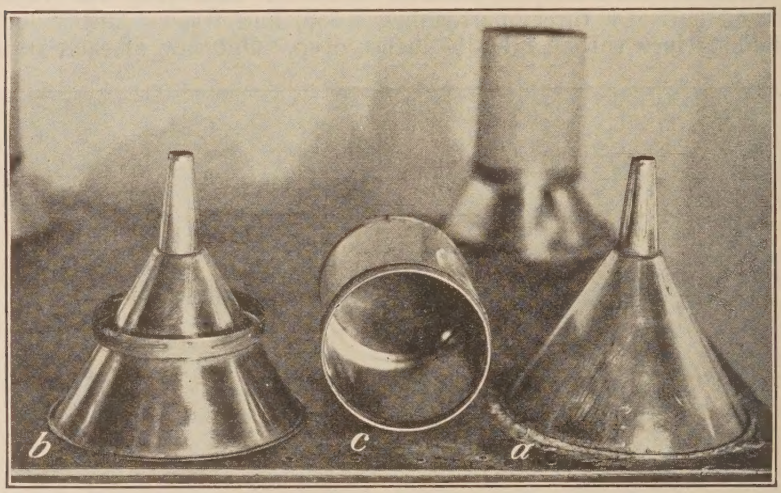

FIGURE 6.—Parts of the automatic collecting can: *a*, Funnel soldered to top of cabinet; *b*, separate funnel with rim of screw lid attached; *c*, can with wire-screen bottom to be inverted and screwed into the rim attached to the funnel *b*.

for 10 minutes in cold water, and was then placed in the 16 trays which were hung in a rack (fig. 8). Rack and trays of grain were immersed 3 minutes in a tank of water heated to 70° C. (158° F.).

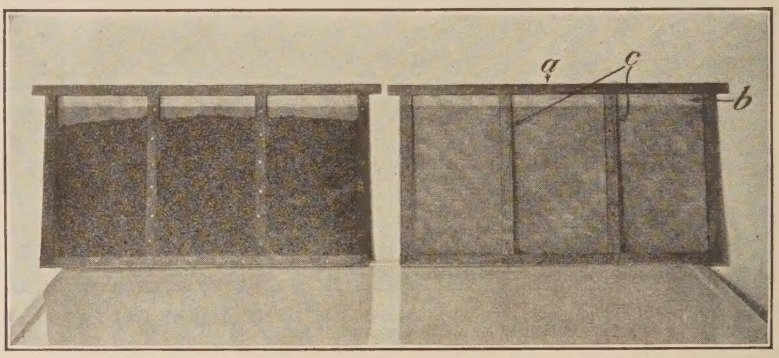

FIGURE 7.—Individual trays, one filled with wheat: *a*, Top bar; *b*, slot for filling and emptying tray; *c*, *c*, braces.

Still in the rack, the trays of wheat were drained and then for 3 days, or until just dry enough to avoid molding when placed in the cabinets, were dried in one of the incubator rooms which was free from flying moths.

To start the infestation, 1,200,000 *Sitotroga* eggs on the cards were placed in eight of the vertical trays through the open slots, on

top of the masses of treated grain, and these trays were set in place in the cabinet. Two weeks later an equal number of eggs were placed in eight more trays, which were added similarly. By introducing the 2,400,000 eggs in 2 fractions, separated 14 days apart, marked peaks of emergence for the adult moths were avoided, and almost uniform daily production was attained. The cards of eggs were

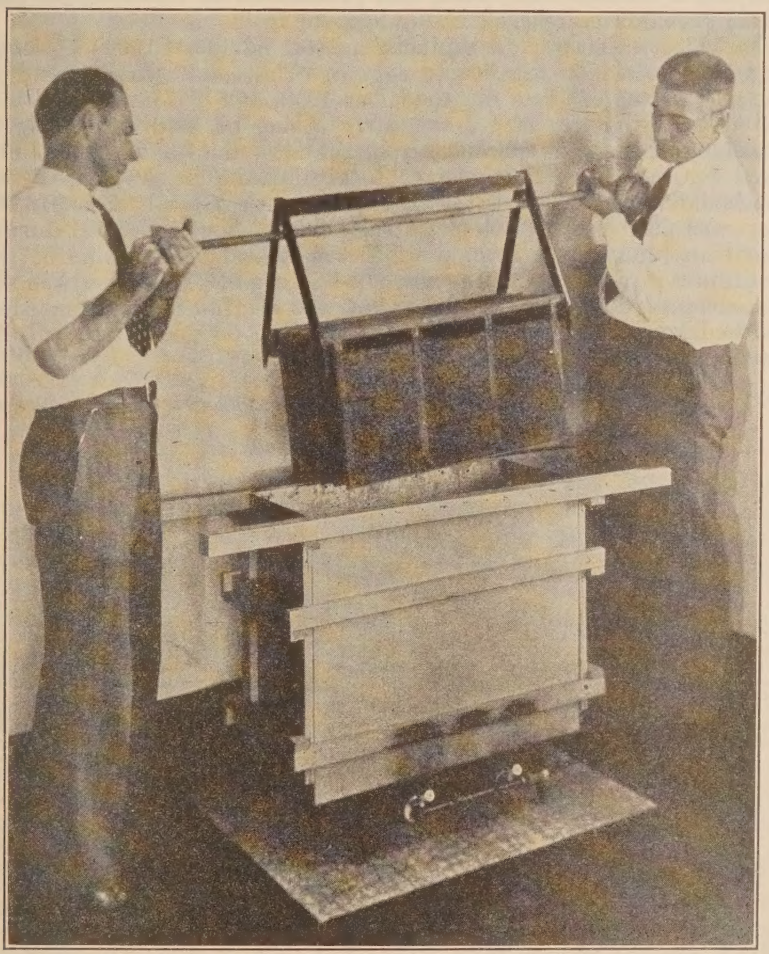

FIGURE 8.—Plunging loaded trays into the hot-water bath for disinfesting wheat and adding moisture.

dipped momentarily in liquid carbon disulphide, for the elimination of mites and other pests, and were quickly dried. This treatment does not affect the *Sitotroga* eggs, which seem to be almost impervious. After 35 days in the incubator rooms at 80° F., infestation had reached levels that were sufficiently high for the removal of the moths by use of the automatic collecting cans. The cabinets could be continued in full production for 2, and sometimes 3, months there-

after. For a continuous production of 1,000,000 *Sitotroga* eggs per day, it was necessary to start 1 cabinet each week, the first unit being ready for restocking the week after the sixteenth was started; the desired maximum being attained 12 weeks from the start, or when 8 cabinets were in full production. Thereafter this production was held uniform at this level as long as eggs were desired. By starting 2 cabinets each week, full production of 1,000,000 per day could probably be reached in 8 weeks.

In 1933, with these 16 cabinets, a total of 125,110,000 *Sitotroga* eggs was obtained. Grain and eggs of *S. cerealella* were placed in the first of the cabinets in September 1932, and the infestation was built up during the winter and early spring of 1933 as rapidly as possible, all the eggs obtained from the first units having been utilized for infesting additional cabinets. Maximum production was reached during March 1933, in which month a total of 25,516,000 eggs was produced. Production was held at about this level during April and May. On account of the improved ventilation for the grain in the cabinets, heating did not occur, and production was not discontinued during the summer, but was continued at a somewhat reduced level until the last of August. The production record, by months, for the 4 years is given in table 1.

TABLE 1.—*Laboratory production of Sitotroga eggs, by years and months, at Albany, Ga., 1931 to 1934*

Month	1931	1932	1933	1934
	Number	*Number*	*Number*	*Number*
November [1]			1, 012, 000	
December [1]			2, 699, 000	
January	47, 000		6, 151, 000	
February	23, 000		7, 165, 000	
March	154, 000	4, 512, 000	25, 516, 000	23, 000
April	4, 092, 000	8, 880, 000	24, 605, 000	1, 035, 000
May	9, 818, 000	12, 257, 000	23, 722, 000	3, 055, 000
June	10, 480, 000	4, 874, 000	13, 840, 000	3, 950, 000
July	830, 000	278, 000	14, 800, 000	5, 000, 000
August	[2]	[2]	5, 310, 000	6, 350, 000
September			290, 000	2, 910, 000
October			[2]	5, 040, 000
November				24, 050, 000
December				24, 550, 000
Total	25, 444, 000	30, 801, 000	125, 110, 000	75, 963, 000

[1] Of preceding year.
[2] Production discontinued for season.

The operation of the new cabinets during 1933 was quite satisfactory, and only a few minor changes in their construction were necessary. Most of the difficulties experienced in 1931 and 1932 were solved. In the narrow trays none of the wheat grains escaped infestation during the period in which the units were in production; thus there was no waste of grain. Ventilation in the cabinets was adequate. The heat of infestation in the narrow, vertical trays of grain assisted in the ventilation, and the more heating there was in the cabinet the faster this system of ventilation operated, since the hotter the air became between the trays the faster it rose and escaped. The hymenopterous parasite *Dibrachys boucheanus* was kept

out of the units by the 60-mesh screening used on sides and on the collecting cans. The gamasid mites and coleopterous weevils could still be found in the cabinets at the end of the production cycle, but these pests did not become abundant enough to influence the *Sitotroga* infestation adversely. The initial routine treatments of the wheat and the thorough screening helped to bring about this improvement.

From the standpoint of production the use of the cabinets was far superior to the incubator-room method previously employed. In this connection it is only necessary to point out that monthly production during each of the months of March, April, and May of 1933 nearly equaled or exceeded the total number of eggs produced during the entire year of 1931 (table 1). The use of the cabinets not only increased the gross yield of *Sitotroga* eggs but also decreased greatly the cost of production. The saving was especially noticeable in the cost of grain. In 1931 and 1932 56,000,000 eggs in all were obtained by the use of 400 bushels of corn purchased for $472; in 1933 24 bushels of wheat costing $24.50 served for the production of more than 125,000,000 eggs in the cabinets. There was also a saving in labor. With the new automatic collecting cans on the tops of the cabinets, only a quarter to a half an hour of labor was necessary each day for gathering the moths where formerly 4 hours was devoted to the operation in the incubator rooms.

COST OF OPERATION IN 1933

An analysis of costs under the new technic employed with the cabinets revealed that the cost per million for the 125,110,000 eggs obtained in 1933 was $6.65. In the following tabulation there is a brief recapitulation of the items in the analysis of which these cost estimates were obtained:

Permanent equipment:		
From previous years	$327.65	
Cabinets, 16 at $23.75 each	380.00	
Ventilating fans, 3 at $8 each	24.00	
Screen wire, 60-mesh	49.50	
Hose for spraying	4.50	
Total		$785.65
10 percent depreciation for 1933		78.57
Fuel (fuel oil)		97.80
Electricity, gas, water [5]		120.00
Glassware and miscellaneous supplies:		
Battery jars	21.60	
Petri dishes	14.50	
Cardboard	3.00	
Paste	7.85	
Fumigants	6.75	
Miscellaneous	11.35	
Total		65.05
Wheat for rearing host insects:		
10 bushels at $1	10.00	
10 bushels at $0.95	9.50	
4 bushels at $1.25	5.00	
Total		24.50

[5] Estimate.

Labor:		
Moth collecting, 330 days, ¼ hour each, at $0.40 per hour	$33.00	
Cleaning eggs, 330 days, 1 hour each, at $0.40 per hour	132.00	
Pasting eggs, 125 million, 1 hour each million, at $0.40 per hour	50.00	
Parasite propagation, 330 days, ½ hour each, at $1 per hour [6]	165.00	
Cleaning glassware, 330 days, 1 hour each, at $0.15 per hour [6]	49.50	
Total		$429.50
Total costs (1933) [7]		815.42
Cost per million *Sitotroga* eggs (125,110,000 produced)		6.51

For the purpose of protecting the rights of the public in this rearing device, and to make it available for use of anyone without payment of fees or royalties, application for a public-service patent was made and, on September 25, 1934, Letters Patent No. 1974549 were granted.

The securing of a public-service patent on this device was made possible through the courtesy of Arthur Gibson and A. B. Baird, of the entomological branch, Dominion of Canada Department of Agriculture, and of Philip Garman, of the Connecticut Agricultural Experiment Station, in permitting the incorporation of certain original features of their own rearing units in modified form in the one here described.

PRODUCTION AND COSTS IN 1934

Because of necessary economies, the mass rearing program for 1934 was not started in the previous December as originally planned, but infestation of the first cabinets was delayed until February 10. There was an unexpectedly early demand for *Trichogramma minutum* for experimental releases in apple orchards in April and May, and this absorbed so many of the *Sitotroga* eggs produced by the cabinets first infested that an insufficient number remained for proper infestation of cabinets put into operation later on. Then, too, full production was further retarded by the untimely appearance of the mite *Pediculoides ventricosus* Newport in five of the cabinets, which were immediately fumigated with carbon disulphide to eliminate this pest.

The fumigation was done by putting the cabinet into a specially constructed fumigation box, designed and made in the laboratory for the purpose (fig. 9).

This box consisted of a shallow galvanized sheet-metal tray, reinforced with wood, measuring 42 by 36 inches, by 1¾ inches deep, and a sheet-metal top, soldered gastight, measuring 45 inches high, 35 inches from side to side, and 30 inches from front to back. Metal handles on this top and the light weight (52 pounds) made the outfit easily portable, and when in use the rearing cabinet was placed in the traylike bottom, the top was lowered over it until the open end rested inside of the bottom tray, and a layer of water in the latter effectively sealed the box and allowed none of the fumigating gas to escape. Carbon disulphide was introduced through an opening

[6] Average.
[7] Rental and cost of supervision not included.

in the top, provided with a screw-type lid, at the rate of 40 ml for the 33 cubic feet of space, and no mites or insect stages survived the fumigation period of 24 hours. The loss of the *Sitotroga* infestation in five cabinets which were fumigated prematurely because of contamination with *Pediculoides* was a serious setback to the rearing program, early in 1934. However, by thorough clean-up methods, and the use of the fumigation box, *Pediculoides* was successfully eliminated.

In spite of a very late start and of the *Pediculoides* infestation, a total of 75,963,000 *Sitotroga* eggs was obtained during 1934 (table 1). A peak yield approaching 1,000,000 host eggs per day was eventually reached and the present program calls for continuance of this daily yield permanently by replacement of exhausted units regularly

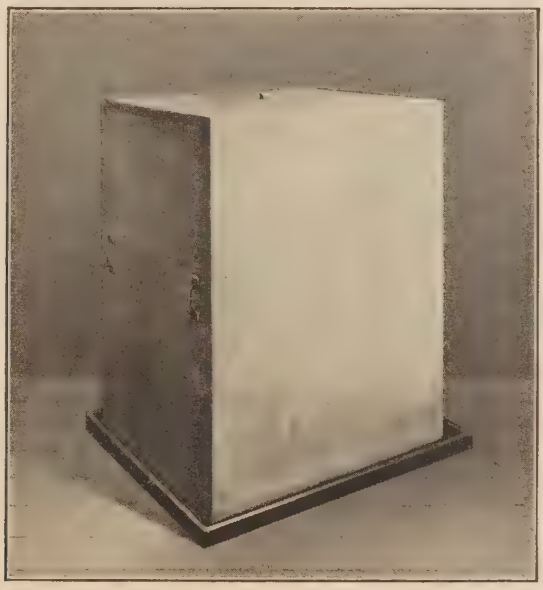

FIGURE 9.—Fumigating box covering a cabinet.

at weekly intervals with freshly stocked cabinets. During the year several small improvements were made in the design of the cabinet (fig. 10). New fronts hinged in the middle, with the upper part bolted tight to the unit and the lower hinged portion arranged so that debris might be removed from beneath the trays without loss of many moths, were attached to all of the units. Removal of dead moths, dust, and other waste products from the bottoms of the cabinets in this way helped to reduce the number of mites and weevils. It was found also that spraying the insides of the units and the trays of wheat twice daily with water materially increased production and induced larger proportions of the moths to enter the collecting cans.

The reduction in total yield of *Sitotroga* eggs in 1934, as compared with 1933, and heavier expenses for humidifying equipment, especially, made the cost per million eggs considerably higher than in

1933. Careful estimates, as shown in the following tabulation, have given a cost figure for 1934 of $9.88 per million eggs, which is much lower, however, than the cost per million in 1931 or 1932, when the original equipment was in use.

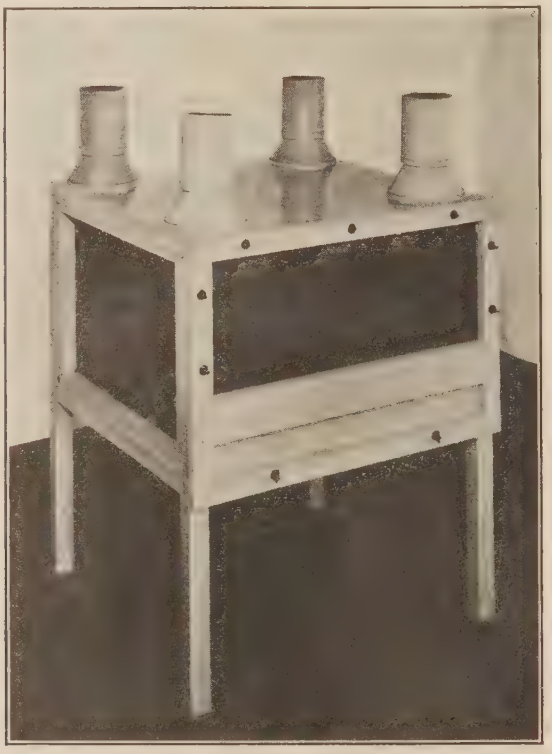

FIGURE 10.—The improved 1934 cabinet.

Permanent equipment:		
From previous years	$785.65	
Humidifying equipment	120.98	
Ventilating fans	16.43	
Gas hot plate	7.75	
Portable fumigating box	5.23	
Tank for dipping grain	2.00	
Total		$938.04
10 percent depreciation for 1934		93.80
Fuel (fuel oil)		119.20
Electricity, gas, water [8]		100.00
Glassware and miscellaneous supplies:		
Battery jars	21.60	
Petri dishes	14.50	
Cardboard	3.00	
Paste	3.35	
Fumigants	11.92	
Miscellaneous	7.00	
Total		61.37

[8] Estimate.

Wheat for rearing host insects:		
20 bushels at $1.35	$27.00	
5 bushels at $1.60	8.00	
Total		$35.00
Labor:		
Moth collecting, 270 days, ¼ hour each, at $0.40 per hour	27.00	
Cleaning eggs, 270 days, 1 hour each, at $0.40 per hour	108.00	
Pasting eggs, 77 million, 1 hour each million, at $0.40 per hour	30.80	
Parasite propagation, 270 days, ½ hour each, at $1 per hour [9]	135.00	
Cleaning glassware, 270 days, 1 hour each, at $0.15 per hour [9]	40.50	
Total		341.30
Total costs (1934) [10]		750.67
Cost per million *Sitotroga* eggs (75,963,000 produced)		9.88

Since the refinements in design of cabinet, in humidifying equipment, and in technic were conceived late in the rearing season of 1934, the benefits derived from their use do not show in the 1934 mass-production results, but may be expected to show in later work. With the 16 cabinets in the Albany laboratory, it should be easily possible to obtain a continuous daily yield of 1,000,000 host eggs throughout the year, if desired; and by special manipulation of the cabinets and by infesting twice the number usually started at weekly intervals production can undoubtedly be maintained at the peak for short periods, so that double this number of *Sitotroga* eggs may be obtained.

COMPARISON OF PRODUCTION COSTS

The totals for the different classes of costs in 1931, 1933, and 1934 are presented in table 2.

TABLE 2.—*Cost of mass rearing of eggs of Sitotroga cerealella in 1931, 1933, and 1934, Albany, Ga.*

Item	1931	1933	1934
Depreciation in value of permanent equipment (10 percent)	$71.95	$78.57	$93.80
Fuel (fuel oil)	63.75	97.80	119.20
Electricity, gas, water [1]	80.00	120.00	100.00
Glassware and miscellaneous supplies	49.07	65.05	61.37
Grain (corn or wheat) for rearing host insects	236.00	24.50	35.00
Labor	416.20	429.50	341.30
Total [2]	916.97	815.42	750.67
Average cost per million *Sitotroga* eggs	36.04	6.51	9.88

[1] Estimated.
[2] Rental and cost of supervision not included.

[9] Average.
[10] Rental and cost of supervision not included.

ESTIMATES OF FLOOR SPACE, ARTICLES OF EQUIPMENT, AND LABOR NEEDED

The following estimates are for the production of 2,000,000 *Sitotroga* eggs daily.

SPACE REQUIREMENTS

All rooms used should have provision for maintaining a constant temperature of 80° F., and if exact control is not feasible the temperature should never be allowed to exceed 94°. A controlled relative humidity between 50 and 70 percent should be provided.

STARTING ROOM

Minimum floor space, 192 square feet. Used for treating grain with hot water, for starting the infestation in newly stocked cabinets, and for incubation in these until moths emerge (35 days).

PRODUCTION ROOM

Minimum space, 576 square feet. Cabinets producing moths are manipulated in this room. The total space may be in three separate rooms.

OVIPOSITION AND PARASITE WORK

Minimum floor space, 192 square feet. The egg-cleaning work should be partitioned off from the parasite-production space because of annoying dust. Two small rooms could be used.

Total minimum floor space, 960 square feet.

EQUIPMENT

Starting room:
- 1 hot-water treatment tank and accessories (fig. 8).
- 10 tightly-covered cans for fumigation of grain.
- 1 table, metal top, 2 by 3 feet.
- 1 scoop for handling grain.
- 1 tray, galvanized, 2 by 3 feet, 4 inches deep.
- 1 metal fumigating box, 45 by 35 by 30 inches (fig. 9).
- 1 fan, 10-inch, nonoscillating.

Production rooms:
- 24 cabinets for rearing moths (fig. 10).
- 1 fan, 10-inch, nonoscillating, for each room.
- 1 metal stool, 24 inches high, for each room.
- 1 hose, ½-inch, with spray nozzle, for each room.

Oviposition room:
- 1 set of seven shelves, 10 feet long, 1 foot deep, and 8 feet high.
- 48 battery jars, 6½ inches in diameter, 8 inches deep.
- 48 screen-wire tops, 20-mesh, for jars.
- 1 table, metal top, 3 by 4 feet.
- 300 Petri dishes.
- 1 rack (fig. 4) for exposing *Sitotroga* eggs to parasites.
- 1 electric refrigerator, small size.

Miscellaneous supplies:
- 100 pounds of carbon disulphide.
- 3 respirators.
- 1 sling psychrometer.
- 4 maximum and minimum thermometers.

LABOR

	Hours per day
Skilled:	
Supervision	1
Parasite propagation	1
Unskilled:	
Collecting moths from cans on cabinets	1
Shaking eggs from oviposition jars	1
Pasting eggs to egg cards	2
Cleaning rooms and glassware	1
Miscellaneous	1

SUMMARY

In 1931 and 1932 the Albany, Ga., laboratory of the Bureau of Entomology, United States Department of Agriculture, engaged in mass rearing of the host *Sitotroga cerealella* Oliv. and the parasite *Trichogramma minutum* Riley, and obtained total yields of approximately 25,444,000 and 31,000,000 host eggs in the respective years. For this work 200 bushels of corn were used each year in trays in two large incubator rooms.

Careful cost estimates, derived from daily records kept throughout this period, indicated that the cost per million of the *Sitotroga* eggs was $36.04 in 1931 and $33.87 in 1932.

Certain undesirable factors which adversely influenced production of *Sitotroga* eggs in large incubator rooms brought about experiments with several types of rearing cabinets and with other grains. These factors were: Waste of grain, inadequate ventilation which brought about heating, entrance of undesirable pests into the rooms, and relatively high costs. A new and improved cabinet for rearing the host insect was designed and patented. It utilized narrow vertical hanging trays of wheat and was fitted with automatic collecting devices. A device for treating grain with hot water for elimination of undesirable insects and mites and conditioning of the grain for starting rearing cabinets, is described. An infestation of the mite *Pediculoides ventricosus* Newport in rearing cabinets was eliminated by use of a metal fumigation box, featuring portability, gas-tight construction, and a traylike door sealed with a water layer during operation.

In 1933 16 cabinets using 24 bushels of wheat costing only $24.50 yielded more than 125,000,000 *Sitotroga* eggs. The cost per million was reduced to $6.51. In 1934, operating under a retarded program, 75,963,000 eggs were obtained with a cost of $9.88 per million.

In 1933 a peak production of more than 800,000 eggs per day was reached and held constant for a 3-month period. In 1934 a similar peak was reached, and production was being continued at a high level at the end of the year.

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